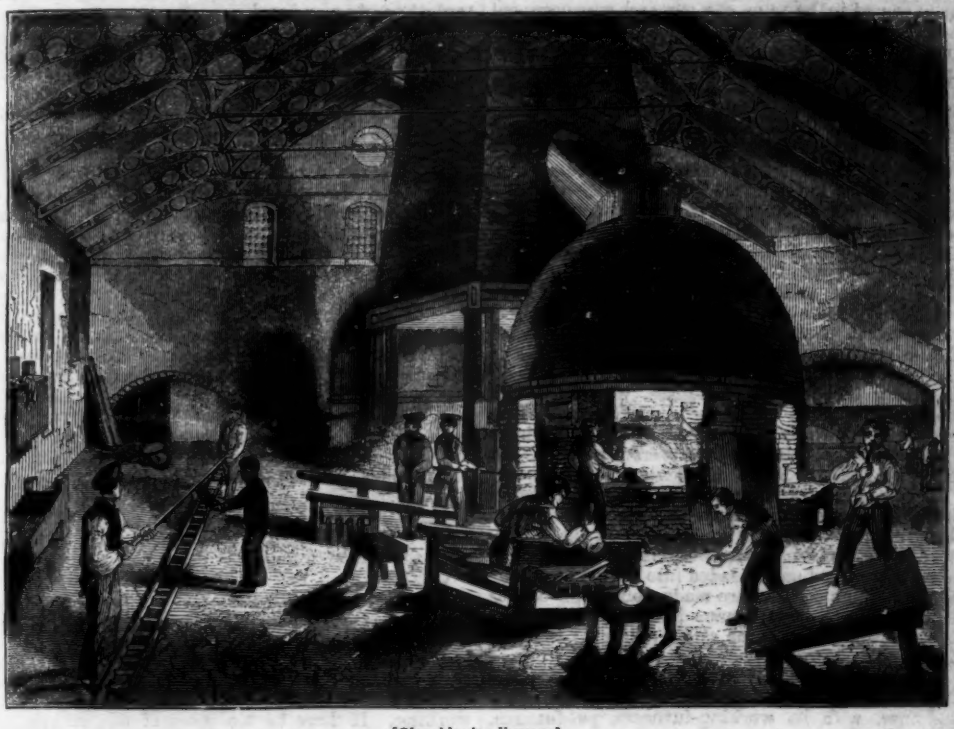
A DAY AT A FLINT-GLASS FACTORY.



[Glass-blowing Furnace.]

'IT might contribute to dispose us to a kinder regard for the labours of one another, if we were to consider from what unpromising beginnings the most useful productions of art have probably arisen. Who, when he first saw the sand or ashes, by a casual intenseness of heat, melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniences of life as would, in time, constitute a great part of the happiness of the world? Yet, by some such fortuitous liquefaction was mankind taught to procure a body, at once, in a high degree, solid and transparent; which might admit the light of the sun, and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him, at one time, with the unbounded extent of material creation, and at another with the endless subordination of animal life; and, what is of yet more importance, might supply the decays of nature, and succour old age with subsidiary sight. Thus was the first artificer in glass employed, though without his knowledge or expectation. He was facilitating and prolonging the enjoyment of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures: he was enabling the student to contemplate nature, and the beauty to behold herself."

A century has nearly elapsed since Dr. Johnson wrote this forcible and beautiful paragraph; and nothing has occurred, in the subsequent history of manufactures, to lessen its truth or beauty. Many opaque substances are capable of assuming a form more or less vitreous or glass-like; such as earths, some acids and salts, and metallic oxides. In porcelain we see an example of partial vitrification; for the granular texture is exceedingly fine, and a slight translucency is produced. But complete vitrification never results until after the fusion or melting of the ingredients; and we know of no means by which porcelain clay or any other earth may be melted in its simple state. But when two kinds of earth are mixed together, or, still better, when a siliceous earth is mixed with certain crystalline salts, perfect fusion may be produced, and a nearer approach to transparent glass may result. Again, certain metallic oxides may be made to assume a vitreous form, and, when mixed with silex, to produce a glass possessing valuable properties. We may thence regard glass, generally speaking, as resulting from the mixture and fusion of these three kinds of ingredients; and the purpose fulfilled by each may be thus understood:—the siliceous substance is the vitrifiable ingredient; the salt or alkali is the flux, by mixture with which the silex becomes fusible; and the metallic oxide, besides acting as a flux, imparts certain qualities whereby one kind of glass is distinguishable from another.

Such is the nature of vitrification, a process which, if we may judge from the researches made within the last thirty or forty years in Egypt, and the discovery of the mode of deciphering the hieroglyphics so profusely displayed on Egyptian monuments, was known in very remote ages. Sir J. G. Wilkinson ('Manners and Customs of the Ancient Egyptians') adduces three distinct proofs that the art of glass-working was known in Egypt before the exodus of the children of Israel from that land, three thousand five hundred years ago. At

Beni-Hassan and at Thebes are paintings representing, in a very rude form, glass-blowers at work; and from the hieroglyphics accompanying them, it is found that they were executed in the reign of a monarch who occupied the throne at about that period. Again: images of glazed pottery were common at the period under consideration, the vitrified quality of which is of the same quality as glass; and therefore the mode of fusing, and the proper proportions of the ingredients for making glass, must have been already well known. Lastly, Sir J. G. Wilkinson adduces the instance of a glass bead about three-quarters of an inch in diameter, which Captain Henvey found at Thebes, and which contains in hieroglyphic characters the name of a monarch who lived fifteen hundred years before Christ.

The knowledge of the manufacture probably travelled from Egypt to Greece, and thence to Rome and modern Europe; and successive improvements have not only brought the art to a high degree of excellence, but have led to its subdivision into several kinds, such as flint-glass, plate-glass, window-glass, and green or bottle-glass making.

Confining ourselves to flint-glass, we now invite the reader's attention to the process of manufacture. The flint-glass works of Mr. Pellatt, which we have been permitted to visit for our present purpose, are situated in Holland Street, Blackfriars, and comprise the various buildings necessary for the production of flint-glass ware; such as a horse-mill, for grinding old melting-pots, as one of the ingredients in the manufacture of new ones; a room wherein ground or powdered clay is mixed and kneaded into a working state; another in which the pots are made; others for drying the manufactured pots; rooms for storing, washing, and preparing the alkaline salts; others for washing and drying the siliceous sand; a mixing-room, wherein the sand, alkali, and oxides are combined; two coking-ovens, or furnaces for converting coal into coke; the glass-house, with its working-furnaces, pot-furnace, and annealing-oven; glass-cutting and glass-engraving shops; and others for subsidiary purposes: the whole occupying an area of about three-fourths of an acre. The routine of operations in these departments will come successively under our notice.

In describing the vitrifiable qualities of various materials, we used the most general terms, in order to include all kinds of glass within our remarks; but it is necessary now to state the restrictions which are required in practice. Although most earthy substances may, by peculiar treatment, be wholly or partially vitrified, yet *silex*, or *flint*, is that which possesses the most valuable qualities. Again, although many alkaline and saline substances might be used as fluxing materials, yet soda and potash, in one or other of their forms, are those generally employed by the glass-maker. Lastly, although many metallic oxides might be similarly vitrified, yet oxide of lead is that which is most frequently employed. This being premised, we may state that the materials for flint-glass are nearly as follow:—One part of alkali (carbonate and nitrate of potash), two parts of oxide of lead, three parts of sea-sand, and a minute portion of the oxides of manganese and arsenic.

The term 'flint-glass' is given because flints were formerly employed as the siliceous material: they were made red-hot, and plunged into cold water, whereby they were so fractured and disintegrated as to be easily ground to powder. Sea-sand is, however, now found to answer the same purpose, at a less expenditure of time and trouble. The sand employed is obtained from the sea-shore at Lynn in Norfolk, and at Alum Bay, Isle of Wight; the qualities brought from hence being superior to most others. A few years ago, a portion of sand brought from Australia as ballast was found to answer the purpose of English sand, and was indeed expected to be superior; we believe, however, that the qualities of the three kinds are now ranked nearly on a level.

The sand, being impure when brought to the works, is conveyed to an upper room, and thrown into a trough containing water. This trough is capable of being closed, and is fixed on horizontal pivots, whereby a rocking motion can be given; and the sand, being thus driven from side to side in the water, and stirred with a spade, loses some of its impurities. The dirty water is emptied into a channel in the floor of the room; and the same process is repeated seven or eight times, until the sand becomes perfectly clean. It is then placed in a trough over an oven, through holes in which it passes, when partially dried, into the oven beneath, and, when dried, leaves the oven in the state of fine, glittering, white particles.

With regard to the alkali employed, there are reasons why potash, in the form of carbonate, is preferable to other kinds; the carbonic acid being, however, dissipated during the melting, and leaving the potash in a pure state. The carbonate of potash is obtained from Canada and the United States, and requires a process of washing previous to use. It is conveyed to an underground apartment, in which are washing-bins, settling-pans, evaporating-pans, and other necessary apparatus. The state to which the carbonate is brought by the process of cleansing, is that of fine white grains, differing but little, to an unpractised eye, from the prepared sand.

Oxide of lead, both in the form of litharge and of minium, or red-lead, is employed in flint-glass for the following reasons:—it is a powerful flux, enabling the sand to melt more readily, and it gives the glass greater density, greater power of refracting light, greater lustre, greater resistance to fracture from sudden heat and cold, and greater ductility during the working. If there be too much of this material, the glass becomes inconveniently soft.

The other ingredients in flint-glass, which are very small in quantity, are used as purifying and bleaching agents; and, as well as the oxide of lead, require but little preparation on the part of the glass-maker.

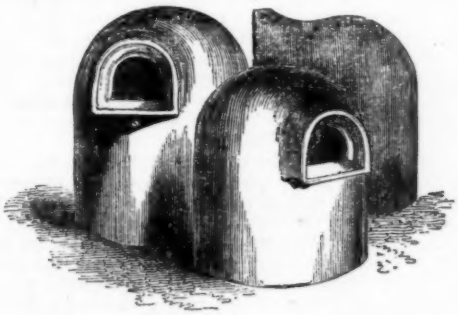
Let us assume that these several ingredients are in a sufficiently prepared state. They are taken to the 'mixing-room,' which contains several long bins or boxes; and after being weighed in proper proportions, the ingredients are sifted, mixed in the bins, and brought to a state fit for the melting-furnace. Here we must leave them for the present, remembering that the state in which the ingredients are put into the melting-pots is that of a salmon-coloured powder, the red tinge being given by the oxide of lead.

The melting-pots, and their mode of preparation, now deserve our notice. The reader will not be surprised to hear that the manufacture, drying, and baking of the glass-pots are important processes; since one pot, when filled, contains sixteen hundredweight of glass, the preservation and proper melting of which are essential to the subsequent labours of the glass-worker.

There is a particular kind of clay, brought from Stourbridge in Worcestershire, which seems better calculated than any other as a material for the glass-pots, and which is dug from the soil in a hard state, ground fine, barrelled, and sent up to London. The broken or worn-out pots are likewise found to be useful when employed in combination with new clay; four parts of new clay being mixed with one part of old pots, ground by a horse-mill, and sifted to fine powder. The mixed ingredients then undergo a process so primitive, that one almost regrets to see it in this age of machinery. The powdered clay, being mixed with warm water in large

square leaden troughs, is trampled on with naked feet until thoroughly kneaded into a stiff adhesive clay. The kneading of the dough for sea-biscuits at Deptford, which was formerly done by men's fists and elbows, is now much better effected by machinery; and we might suppose that a similar result would follow the application of machinery in the present case; but it appears that a machine, formerly employed at these works for this purpose, failed to produce the required effect, and the old method was again resumed.

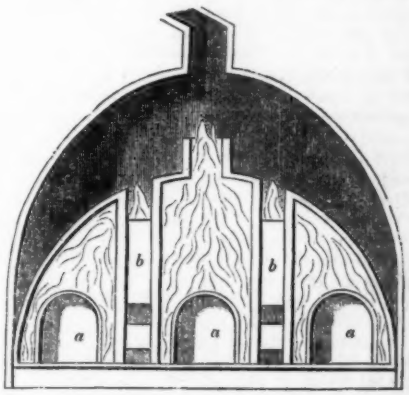
The services of the 'pot-maker' are now called for. The melting-pots for flint-glass are not moulded, but are built up piecemeal, each piece being rolled into a cylindrical form, and laid in a curve on preceding rolls. If we could imagine a boy's grotto to be built of these clay rolls instead of oyster-shells, we might form an idea of the potter's operations, with this important addition, that every roll of clay is so thoroughly pressed and squeezed as to expel all the air from between the rolls, and to form a uniform and thick wall or crust. The manipulations of the potter are aided by a few simple tools; and, keeping four in progress at once, working a little on each in turn, he completes the four in six days. Few persons, probably, on hearing of a 'melting-pot,' would imagine the weight and bulk of those here alluded to. The weight of clay required for one pot is nearly one thousand pounds; and the dimensions of the finished vessel are about three feet in height, two and three-quarters in diameter, and from two to three inches thick. The shape is nearly cylindrical, with a hemispherical top and a flat base, and there is only one opening, about eight or ten inches in diameter, at the upper part of one side.



The longer these pots can be left before they are used, the better; consequently it is important to keep a considerable number on hand. We were struck with the singular appearance of a large dark room, the floor of which was studded with nearly a hundred of these dome-shaped vessels. A little stretch of imagination would have transformed the assemblage into Cassim Baba's oil-jars, and have peopled them with forty (or twice forty) thieves; but the damp odour of clay kept the thoughts from wandering from Blackfriars to Bagdad. The pots are left in this room for several months. The evaporation from the damp clay is considerable, and is allowed to go on very gradually, in order to ensure an equable state throughout the thickness of the pot. When the drying is effected, the pots are taken as wanted to an adjoining room, kept at a higher temperature, and then, a door being opened into the glass-house (of which more presently), each pot is lowered by a crane, and placed in the 'pot-arch.' This arch is a small furnace capable of containing two or three pots; and the pots are there exposed for five days to a very intense heat.

The ingredients are prepared; the melting-pots are made and hardened; and it is now time to visit the 'glass-house' itself—the part of the building to which all the others are subsidiary, and to which the eye of an artist might be directed for some striking effects of light and shade. Imagine a large room, fifty or sixty feet square, with an earthen floor, bounded by brick walls, lofty and dimly lighted, and covered by an iron roof, the middle of which is probably fifty feet from the ground. This is the shell or crust, the kernel of which is the melting-furnace. In the middle of the room we see four pillars, twelve or fourteen feet high, supporting the four corners of a great chimney, which passes through the middle of the roof, and rises to a height of about eighty feet. This chimney is quadrangular, tapering upwards; and a clear passage is left beneath it between the pillars. Built on the level of the ground, at two opposite sides of this chimney, are two furnaces, the smoke from each of which ascends by a bent flue into the great chimney. Such are the objects which first meet the eye through the dusky gloom of the place.

As the two furnaces closely resemble each other, we will, for convenience of description, speak as if there were but one. The furnace is a circular dome, about fifteen feet in diameter and the same in height; and its internal construction may be understood by supposing two basins, one shallow and the other deep, to be inverted and placed one on another, the shallower



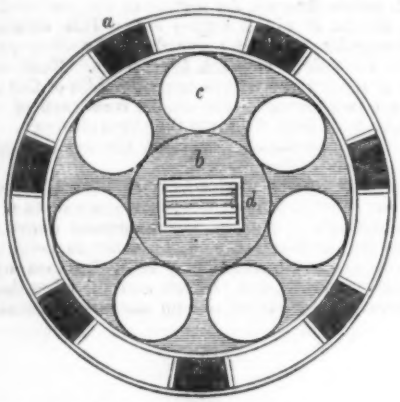
[Section of Melting-Pan. *a*, the pots; *b*, flues.]

one underneath. The inner basin encloses a space containing the pots, the fuel, and the flame and smoke arising therefrom; this flame and smoke reverberate from the vaulted roof, and pass up through flues into the cavity between the two basins, whence the smoke passes, by a bent pipe, into the chimney. All is constructed of brick, and lined with clay capable of resisting the fiercest heat.

The fuel for this furnace is laid on an iron grating in the middle, in connection with which, and beneath the glass-house, is a series of passages running in various directions to the extent of some hundred feet, and intended to furnish the channels for a powerful draught, which, passing upwards through the grating, keeps the fuel in an intensely ignited state. The roof of the inner dome of the furnace is about five or six feet from the ground; and the flame and heated air, reverberating from this roof, maintain a very high temperature within the internal area.

Formerly, the fuel employed used to be coal, but it is now found that in London many advantages result from employing oven-burned coke instead. In a distinct part of the building two coking-ovens have been

erected, for the purpose of preparing the coke on the premises. Into these ovens, which are nearly circular and very shallow, is put small coal, such as is brought from the pit-mouths in Northumberland; and after twenty-four hours' burning or roasting, during which the inflammable matters are driven off, the fuel is drawn out in the form of coke. Twenty-one tons of coal per week are, on an average, required for the glass-house; and this is converted into about fifteen tons of coke in the coking-oven, before being conveyed to the melting-furnace.



[Ground Plan of Melting-Furnace. *a*, flues; *b*, seague or ground on which the pots, *c*, are placed; *d*, grate-bars.]

The melting-pots being of large dimensions, openings, or arches, of sufficient size are left in the sides of the furnace, to allow of the pots being introduced; after which the openings are bricked up. A pot, when once introduced into the furnace, is seldom removed until worn out; but as the average duration of a pot is not more than two or three months, these removals frequently occur. The withdrawal of an old pot and replacing it with a new one is called 'setting a pot,' and constitutes the most arduous and indeed fearful operation of the glass-house, and the one to which the men are wont to refer as proof of their power of heat-endurance. It frequently happens that the old pot breaks, and the pieces, becoming partially vitrified, adhere to the bottom of the furnace: in such case the men stand in front of the fiercely heated openings, and dig up and remove the broken fragments of pot by means of crow-bars and other instruments. While the removal of the old pot is in progress, the new one is kept at a white heat in the 'pot-arch,' a pot-furnace within a few yards of the melting-furnace; and when the transference is to take place, the door of the arch is opened, a low iron carriage is wheeled in and tilted so as to lift up and draw out the pot, and the latter, at a glowing white heat, is wheeled to the furnace, and there deposited in its proper place. When the adjustment is properly made, the opening is immediately bricked up. The temperature to which the men are exposed in this operation (which sometimes takes several hours) may be imperfectly imagined when we remember that the other pots in the furnace may at that time be at a perfectly white heat.

In some kinds of glass manufacture, open melting-pots are used, whereby the fusion of the ingredients is effected in a shorter time. But flint-glass is liable to be injured by the carbonaceous and gaseous matters arising from the fuel, and therefore the pots are covered in. Each pot is so placed in the furnace, that the mouth shall be directed outwards; and this projecting mouth is so bricked and clayed round as to prevent the escape of flame. By this arrangement, every part of the pot, except the mouth, is surrounded by a fierce heat; and although, on looking through this orifice from without, a fiery whiteness is seen, yet this results from the interior of the pot, and not from the interior of the furnace itself, the latter being entirely shielded from view.

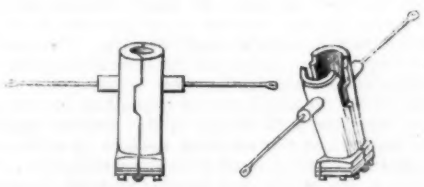
Such is the melting-furnace, provided in this way with seven pots; and we now follow the routine of processes connected with the melting.

The management of a glass-house, in respect to *time*, is somewhat curious and worthy of note. The filling and emptying of a melting-pot are in general so managed as to occupy one week. On Friday morning, the necessary arrangements for filling commence. The mixed ingredients are brought to the furnace in wooden vessels, and then thrown into the pots by means of shovels, through the openings before alluded to. About four hundredweight is put into each pot; the mouth is closed; the fire kept burning strongly; and the ingredients allowed to sink and melt. Three or four hours afterwards, the hole is again opened, another equal supply thrown in, and another equal space of time allowed to elapse. This is repeated four times, until each pot contain its full quota of about sixteen hundredweight. When all the pots are filled, every orifice is stopped up, the fuel is urged to vivid combustion by increased draught from beneath, and the ingredients remain throughout Saturday and Sunday exposed to an intense heat. At stated intervals a small opening is made, and a little of the 'metal' (as the glass is technically termed) is withdrawn to test its progress. In some glass-works, a considerable quantity of scum rises to the surface of the glass while melting; but there is not much in a flint-glass furnace, on account of the purity of the materials, and this little is removed by skimming. We may here observe, that without any wish on the part of the proprietor to deviate from usual customs, a glass-house furnace must necessarily be kept heated on Sundays as well as other days; but the week is so apportioned as to leave as little as possible to be done on Sundays; nothing, indeed, but to watch the furnace: each man having three Sundays out of four at liberty.

On Monday morning all is ready for the glass-workers; the pots are full of 'metal,' looking like liquid fire, and a large party of workmen assemble round the furnace. The mouths are opened, so as to afford access to the melted glass; and smaller holes are opened also, at which the working-tools are heated.

Flint-glass ware, such as drinking-glasses, cruets, decanters, lustres, lamp-shades, phials, &c., are made partly by blowing, partly by manual working, and, in a smaller degree, by moulding or casting, in a way which we will endeavour to describe. We first saw some four-sided perfumery bottles made. A man took a hollow iron tube, about five feet long and half an inch in diameter, and, dipping one end into a pot of melted glass, collected a small quantity at the extremity. The glass appeared like a projecting lump of red-hot iron, and, from its consistence (between that of treacle and of putty), was just able to be retained on the tube. He then rolled the glass on a flat plate of iron, thereby giving it a cylindrical form, and pinched a part of it, by means of a small instrument, to form the neck of the bottle. He next inserted the end of the tube into a small brass mould lying on the ground, shut up the two parts of which the mould consisted, and blew through the tube. This double operation produces a curious effect; for while the air from the lungs, passing through the tube, makes the mass of glass hollow, the mould at the same time imparts to it the external form required. The mould being opened, the glass—now in the form of a bottle—was withdrawn,

still adhering to the end of the rod, and was detached by a slight touch with a piece of cold iron. All this was done in about half a minute; and during the latter part of the process, another workman was gathering and rolling a similar portion of glass, so that one mould served for both. As the bottles were severed from the tube, they were taken up on the end of a heated rod by a third workman, who re-heated them (for by this time they were below red-heat), and by means of a few simple tools finished the necks and mouths as fast as the other two could make the bottles. The lower of the two following cuts represents one form of mould used by the glass-worker.



A far more skilful operation was the production of a claret-jug, since no part whatever of this vessel was moulded. The workman, with a heavier tube than the one before alluded to, gathered a considerable quantity of metal; whirled it twice or thrice round his head, to elongate the mass, rolled it on a flat iron

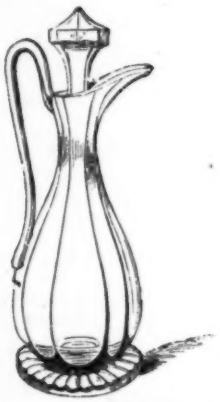
plate; to give it a regular shape; and blew through the tube from the other end, to make the glass hollow. The rolling and blowing having been repeated two or

three times, another workman received it, and sat down in a chair having two flat parallel arms sloping downwards. Then, resting the tube on these arms, he rolled it backwards and forwards, to keep the glass from bending; and a boy, stooping down at the other end, blew through the tube, whereby the mass of glass was maintained hollow. By the aid of an elastic instrument, shaped nearly like sugar-tongs, the workman brought the mass into form, rolling the tube continually, and heating the glass frequently to preserve the

proper consistence. Another workman, called the 'footer,' then brought a little melted glass on the end of a rod, and applied it to the end of the blown mass, to which it instantly adhered. This was soon shaped into a foot; and the whole was transferred from the tube to a rod called the 'punty,' the latter being made to adhere to the foot of the vessel by a little melted glass, and the tube being detached by a touch with a piece of cold iron at its junction with the glass. The glass thus transferred, the making of the upper part of the vessel proceeded. With the aid of scissors, a piece of glowing glass was cut off, so as to allow of a depression for the lip of the jug, and the edge was bent and curved with a dexterity altogether beyond the scope of description. Sometimes one prong, sometimes both prongs of the tongs were inserted in the mouth of the jug, and the internal cavity, as well as the external surface of the jug, were gradually modelled into shape. An attendant workman next brought a smaller mass of melted glass on the end of another rod, which was attached to the vessel, and curved in the form of a handle by a few delicate manœuvres.

The rapidity with which these operations are effected almost baffles the eye of a spectator. The glass is in such a medium state between a solid and a liquid, that while, on the one hand, it would drop from the tube if

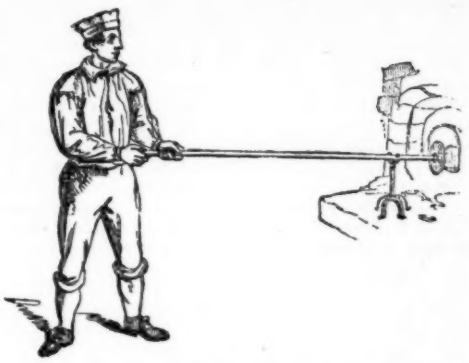
not kept rotatory, it is, on the other, capable of being pulled, twisted, stretched, cut, pressed, and worked in various ways. No mould, stamp, or press was employed in the manufacture of this jug, the whole being effected by the manual dexterity and accurate eye of the workman, aided by a few of the most simple tools. Great, indeed, is the surprise excited at seeing such an elegantly-formed vessel manufactured in such a way in the space of ten or twelve minutes: we here allude to the making only, for in the annexed figure the jug is represented in its finished or 'cut' state. The eye



of the workman detects when the glass is becoming too cold for working, and he holds it for a few seconds at the 'working hole,'—one of the pot-mouths. After every such re-heating, he sits down again, and rolls the tube in the 'chair-arms,' with the glass projecting over near his right hand.

In all vessels provided with a leg and foot, such as wine-glasses, the leg is formed of one dip of glass, and the foot of another, each in turn being attached to the body of the vessel, and worked into shape. In such articles as salvers, dishes, or shallow vessels generally, the workman, after having his mass of glass hollowed by blowing, transfers it from the working tube to the punty: the hole left where the tube had been attached he gradually enlarges, by whirling, modelling, re-heating, and bending, until the glass expands to the wide flat concave form required. In any vessel to be provided with a handle, a lump of glass—if we call it *glass putty*, perhaps the reader will form a better idea of its consistence—is attached at one spot, drawn out, dexterously curved, and attached also at another spot, an operation nearly as surprising as any in the manufacture, since the workman has no guide but the accuracy of his eye in suddenly forming the handle. In such a production as a lamp or chandelier shade, the mass requires frequent re-heating, on account of the large size attained; and whenever the mass of glass has to be thus repeatedly heated, a constant rotation is given to the tube or rod, to preserve a circular form in the article attached to it. While re-heating at the furnace, this rotation is maintained as much as on the 'chair-arms,' a resting-groove being placed in front of the furnace-mouth for the support of the rod while rotating.

The ductility of the melted glass, or that property by which it is capable of being drawn out, is perhaps nowhere so strikingly shown as in the making of glass-tubes, such as are employed for thermometers, barometers, &c. A workman collects a quantity of glass on the end of a tube, rolls it on an iron plate into a cylindrical form, blows into it to form a cavity within, and holds it towards a second workman, who attaches



a heated rod to the other end of the mass, to which it instantly adheres. The two men, standing opposite each other, then walk backwards, the glass elongating as they proceed, until a tube forty or fifty feet long is produced. This tube hangs down as it is formed, and rests on a ladder or frame laid along the floor of the glass-house; and by the time all the mass of glass is thus drawn out, a tube almost perfectly equable in thickness is formed, with a bore or perforation running through its whole length. The preservation of this bore is one of the most singular parts of the process, the elongated tube acquiring a bore of the same *form* as is given to the cavity in the mass of glass, however much reduced in size. In most thermometers the mercurial column is seen to be flattened, so as to be scarcely visible when viewed laterally. This flattened shape represents the form of the bore of the tube; and in order to produce it, the mass of glass, after having been blown hollow, is gently pressed on two opposite sides, whereby a flattening of the internal cavity is produced while the external surface is again made cylindrical by re-dipping into the melting-pot. This form, *i.e.* flat within and circular without, is retained throughout the subsequent elongation, notwithstanding the vast diminution in the sectional area of the tube Most kinds of glass-tubing, for meteorological, optical, or other purposes, are produced in a manner nearly analogous to that here described; the length of tubing being afterwards cut into convenient portions. Most persons have probably seen or heard of "Glass-working exhibitions," in which trinkets and toys are made in a very delicate and neat manner out of melted or softened glass; although the glass is, in these cases, melted at a blowpipe instead of a furnace, yet the principle by which the exhibitor is enabled to proceed is the same as that developed in tube-making, and calls for our assent to the remark that 'flint-glass possesses, at the working heat, a degree of tenacity and ductility not to be found in any other substance in nature.'

Four thousand pounds weight of glass is weekly wrought into these various articles; and we must now quit the melting-furnace, and watch the manufactured articles in the process of 'annealing.' The object of this process is to render the glass less brittle, and less liable to fracture from sudden alternations of temperature. If a glass vessel, made at the high temperature necessary for working, were allowed at once to cool in the open air, the surfaces of the vessel would cool and contract more rapidly than the interior substance, whereby the glass would be in an unequable state of elasticity, and therefore liable to fracture. We have seen a piece of thick glass-tube, which had been plunged while hot into cold water: the interior surface was cracked to such a degree as to appear like a surface covered with crystals. There are

philosophical toys, known as 'Bologna phials' and 'Prince Rupert's Drops,' which are similarly treated, by being plunged into cold water while yet hot: the exterior becomes cooled and fixed before the interior has time to contract in a corresponding degree; the consequence of which is, that this unusual state of tension causes the whole to be shattered to atoms when the smallest incision or scratch is made on the surface. To avoid such an inconvenience as this, glass-ware is suffered to cool by very slow degrees.

This slow cooling takes place in an annealing-oven called a 'leer;' a name for which it would not perhaps be easy to furnish a reason, unless it be an instance of the Anglicised foreign terms used in a glass-house, and of which the 'punty,' or working rod, and the 'marver,' or iron plate, furnish examples—these two terms being derived from the French 'pontil' and 'marbre.' The arched entrance to the 'leer' is seen at one side of the glass-house, closed by iron doors; the oven having the form of a long flat arch, sixty feet in length or depth, five feet wide, and from one to two in height. Adjoining the door of the oven on each side is a furnace, by which a high temperature is maintained; but as there is no other heating-power, the oven experiences less and less of the heat as the distance from the mouth is greater, until, at the remote extremity, the temperature is scarcely higher than that of the surrounding atmosphere. Along the floor of the oven is a miniature railway upon which two rows of iron trays, called 'leer-pans,' travel.

Such being the arrangement, and all the operations being in full play, the annealing proceeds as follows:—As soon as a glass vessel is formed, a boy carries it, either on a wooden shovel or by means of a pronged fork, to the 'leer,' and places it in one of the pans. This continues until one pan is full; and the pan being then wheeled onward by means of a windlass, another is laid in its place, similarly filled, and similarly wheeled on; and so on, one pan after another. By this means, the pan first filled is drawn farther and farther from the heat, whereby the annealing or gradual cooling is effected. The time required for annealing varies from twelve to sixty hours according to the thickness of glass in the article manufactured; and matters are so arranged as to have similar articles in the oven at one time, in order that the same routine may be available for all; or else to make the two rows of pans travel with different speed. There are some annealing-ovens in which the process is differently conducted: they are much shorter, and more equably heated in the different parts; and after being filled with manufactured articles, the mouth is closed, and the fire allowed gradually to go out, whereby the whole oven loses its heat by slow degrees. The form first described is, however, found most advantageous in the flint-glass manufacture.

The order of processes now requires us to visit a room at the remote end of the annealing-oven. The key of this room is in the possession of an excise-officer, under whose supervision all the arrangements of the room are conducted. Were this the place, we might remark on the evils resulting to manufactures from the mode in which excise duties are collected on the articles manufactured; but we must take the case simply as we find it. The annealed vessels are removed from the pans, examined to see that they are perfect, and weighed; a duty being payable on such articles only as leave the annealing-oven in a perfect state. This restriction is necessary, for the vessels are frequently spoiled in the oven, either by being imperfectly annealed, or by being overheated near the furnace.

Many articles of flint-glass ware are deemed finished when they leave the annealing-oven, and are accordingly warehoused; but the brilliant display of a side-board or dinner-table owes much of its attraction to the cut, or, if the term be allowable, sculptured forms of the glass vessels. This cutting is effected after the vessels are annealed, in a distinct part of the building, and by a process wholly different from those hitherto described.

The glass-cutting room has a singular appearance. A double work-bench extends along the room, divided into several compartments for an equal number of men. In front of each workman is a thin wheel revolving on a horizontal axis; and above some of the wheels are vessels containing sand and water, which drop through a small orifice in the bottom, and fall on the edge of the wheel. All the wheels are set in motion by steam-power, and each workman has the means of unfixing his wheel, and putting on another of a different kind. These wheels are of various sizes, and made of various substances, such as cast-iron, wrought-iron, Yorkshire stone, and willow-wood. The edge of the wheel is that part by which the grinding is effected; and different shapes and thicknesses are given to these edges, in order to produce different results.

The workman takes the glass, decanter, or other manufactured article, and holds it against the edge of the revolving wheel, by which the substance of the glass is ground down, and flat or curved surfaces produced. The vessel is held in various positions, according to the pattern required; accuracy of eye and steadiness of hand being indispensable in the workman. The iron wheels, with sand and water, are used for grinding away the substance of the glass; the stone wheel, with clean water, for smoothing the scratched surfaces; and the wooden wheel, with rotten-stone and putty-powder, for polishing.

In a separate room the stoppers or stopples for bottles are ground, and the necks of small bottles made truly circular by attaching them to a kind of lathe, and applying small tools to the surface while revolving. The value of well-stoppled bottles to the chemist renders this operation one of nicety and importance.

In addition to the cut surfaces of glass vessels, whereby such a lustrous play of colours is produced, the more costly articles are engraved, that is, devices are cut on the surface more delicate than can be produced by the cutting-wheel. A separate apartment is devoted to the operations of the glass-engraver, who is seated at a bench before a small lathe; and to this lathe he attaches one of a series of little metallic disks or wheels, generally made of copper, and varying from an eighth of an inch to two inches in diameter. The edge of the rotating disk he touches with a little emery moistened in oil, and then holds the glass vessel against the edge of the disk, by which very minute scratches or indentations are produced. By dexterous changes in the position of the glass, and in the form and size of the disks employed, he combines these indentations so as to produce beautiful intaglios or sunken pictures.

This is strictly a branch of the Fine Arts, and as such places the engraver on a different level from the other workmen. Taste, both natural and cultivated, a knowledge of the external forms of natural objects, and a delicacy of eye and hand, are all required in this operation; and we viewed with pleasure the labours of an intelligent workman engaged therein. A laudable attempt is now being made in England to diffuse among workmen a more extensive knowledge of the Arts of Design than has yet been possessed by them; and such operations as those of glass cutting and engraving afford an ample field for the display of this kind of knowledge. We believe that the proprietor of this establishment is himself one of the council in the new government School of Design.

The most profitable and important articles of flint-glass are such as are largely employed and have a current sale; but the costly and delicate articles occasionally produced call for great skill and inventive ingenuity. There is a kind of cut-glass in which the projecting parts of the pattern are coloured and the sunken parts colourless. These are produced in a remarkable way; for after the working-tube has collected nearly sufficient colourless glass from one pot, the mass is dipped into another containing glass which is coloured by the addition of certain metallic oxides, by which an external coating of coloured glass is given to the mass. When the blowing and modelling are completed, this exterior coating is, in the finishing process of cutting, ground away in some parts and left remaining in others, thus producing a singularly delicate effect.

Another kind of ornamental manufacture is the 'crystallo-ceramie,' or glass-incrustation, patented by Mr. Pellatt some years ago, and consisting of an opaque substance imbedded in a mass of colourless glass. A medallion or bas-relief, representing any device whatever, is moulded in a peculiar kind of clay capable of resisting the heat of melted glass; and the medallion is enclosed between two pieces of soft glass, or else is introduced into a cavity in the glass, from whence the air is afterwards extracted. The introduction of the medallion into the glass is the main difficulty in this process, and requires much skill and ingenuity, in order that no air-bubbles may exist between the two substances. When finished, and the external surface of the glass cut to the required form, the appearance of the imbedded medallion is singularly chaste and elegant; for the white clay, seen within the clear and highly refractive glass, presents an appearance nearly resembling that of unburnished silver. This branch of art, *i.e.* the incrustation of clay devices, was invented by a Bohemian, about sixty years ago; at a later period some French manufacturers encrusted medallions of Napoleon in this way, and sold them at an enormous price; but since the introduction of the art into England, under an improved form, a wide extension has been given to its applicability. Decanters, goblets, wine-glasses, lamps, girandoles, chimney-ornaments, plates, door-handles, and other articles formed of flint-glass, have been ornamented in this way; the incrustations being arms, ciphers, crests, inscriptions, portraits, small busts, caryatides, or indeed any small objects capable of being modelled or moulded in clay. The incrustation may be painted with metallic colours, which will remain uninjured by the heat required in the process.

There is a mode of incrusting opaque ornaments or devices on the surface, instead of within the substance, of the glass. This is effected by adjusting the ornament in a brass mould, and blowing and moulding the glass to it; the details requiring considerable skill, but the principle being nearly the same as in the other process.

The astronomer and the optician obtain from the flint-glass manufacturer the materials from which their lenses are made. It has been ascertained that there is a certain state of the fused glass which is best calculated for optical purposes; and when the mass has attained this state, about seven pounds weight is taken up in a conical ladle and blown into the form of a hollow cylinder. This cylinder is cut open, and flattened into a sheet twenty inches long by fourteen wide, and from two to three eighths of an inch in thickness. In this form it passes into the hands of the optician, who cuts and grinds it to the shapes required for optical purposes. The masses of glass for large telescope lenses require a somewhat different process, and extraordinary care in the choice, preparation, mixing, and melting of the ingredients: indeed, the production of good glass for this purpose is one of the most uncertain things in the whole glass-manufacture.

We terminate our visit by alluding to the elegant show-rooms or galleries, in which the finished materials, of all the various kinds above alluded to, constitute a brilliant display.